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THE IDENTIFICATION OF PSYCHOPHYSIOLOGIC CORRELATES OF COGNITIVE PROCESSING

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Impact Statement and Summary

"It is becoming increasingly apparent that man and machine must interface through the medium of a computer in terms of having the computer become an extension of his brain the matter of piloting or monitoring and controlling advanced aircraft systems. In this respect, a requirement exists for monitoring the brain activity of the pilot, evaluating his workload, his decision-making ability, his workload processing ability and his capability to respond to the system interface." (Dr. Deanna S. Kitay, Consultant, Airline Pilots Association)

The series of studies conducted in this one-year feasibility study have demonstrated a relationship between electroencyphalographic (EEG) changes and kinds of cognitive processing. Of great importance is the fact that the inherent brain wave patterns from selected scalp electrodes show changes reflecting when the human neurophysiologic system is overloaded or stressed.

Based upon this important initial information, it is possible to explore factors affecting cognitive functioning and decision-making capacity, extending this to the bottom line determination: Can this systems operator or aircrew perform this specific task or mission!

While it may be desirable, if not ultimately necessary, to monitor aircrew brain activity in flight, a more immediate goal will be the ability to reliably predict aircrew performance from controlled stimuli and electrophysiological data samples some time before take-off or during turn-around times. The value of predicting sustained high levels of performance and avoiding the consequences of aircrew error is obvious and far reaching.

Many years ago McKenzie and Hartman (1979) found that one of the crucial

factors affecting aircrew and systems operator performance was information input or processing. Now, for the first time, there is a high probability of predicting cognitive overload for individuals on the basis of inherent EEG (and perhaps other neurophysiologic data). Cognitive overload has greater effects than work/rest cycles, diurnal variations and so forth in producing decremented performance which must be recognized and contravened if the man-machine interface is to be successfully maintained.

In summary, then, several groups of subjects were used to demonstrate the relationship between EEG and cognitive states. The first group of five subjects had two frontal EEG electrodes referred to an indifferent vertex lead. The results showed that there was a difference between cognitive conditions, but that frontal EEG electrodes alone were inadequate to capture the most significant data.

In the next study, 20 subjects were instrumented with six electrodes (two frontals, two centrals and two occipitals) all referred to the ears. The results showed that the best statistical indicator of a difference in cognitive states were the occipital electrodes. Moreover, the results strongly suggested that we would profit by having additional control data on each subject. Therefore, ten of the subjects were also given a deep relaxation exercise. The EEG recorded during the deep relaxation contrasted sharply with that of the cognitive task. However, it was apparent that basic individual subject differences in EEG patterns were distorting the data. Therefore, an additional flight of eight subjects was tested in a statistical design using each subject as its own control and having both cognitive and control tasks presented in close temporal proximity. These results showed

that the EEG is statistically significant and can indeed differentiate cognitive and non-cognitive tasks.

One of the important contributions of this study is the development of a technique to statistically analyze each subject's EEG while using that subject as its own control. This technique is a temporal analysis of a totally within, single subject design, which we refer to as INNOVATE (Individual Nominal Varient Analysis Technique).

Introduction

Historically, studies in electrophysiology have attempted to identify aspects of consciousness by means of specific components of EEG activity (Ehrlichman & Winer, 1979). Recently, such research has looked for relationships between inherent frequencies and cognitive processing (Hyman, 1978). EEG analysis can be a powerful method in studies of brain mechanisms relating to cognition. There have been several indications that an increase in the theta frequency range, (4-7 Hz), along with a decrease in the alpha (8-13 Hz) and beta (14-20) ranges is indicative of cognitive states (Morgan, 1974; Hyman, 1978; Gevins, Zeitlin, Doyle, Yingling, Schaffer, Callaway, and Yeager, 1979). Complex scalp distributions of EEG features generally differentiate among cognitive tasks.

Power spectrum analysis has shown substantial reliability in the study of task related EEG (Ehrlichman & Winer, 1979). Gevins, et.al. (1979) used multivariate pattern recognition analysis to derive EEG spectral signatures which correctly classified unknown EEG samples as coming from one or another of a pair of tasks. However, the EEG differences could not be specifically associated with the cognitive differences between the tasks. It is likely that EEG patterns which discriminated between the tasks were due to intertask differences in efferent activities, stimulus characteristics or performance related factors rather than cognitive differences. In the present study, such intertask differences (e.g. limb movement, and performance-related differences) are relatively controlled because the subjects performed only one task. The task, developed by Captain Layne Perelli (1980), involves no change in response, only in the rate of response. Thus, the subject is

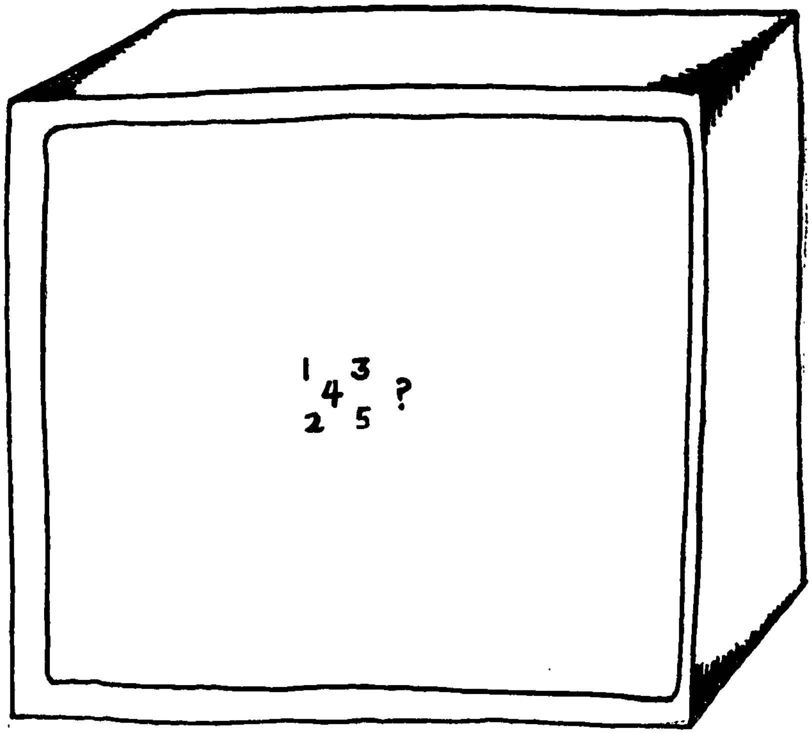
essentially doing the same thing throughout the experiment. The independent variable, then, is the task condition, or the rate at which trials are presented. It is the author's contention that it is the subject's cognitive behavior which is manipulated by this task.

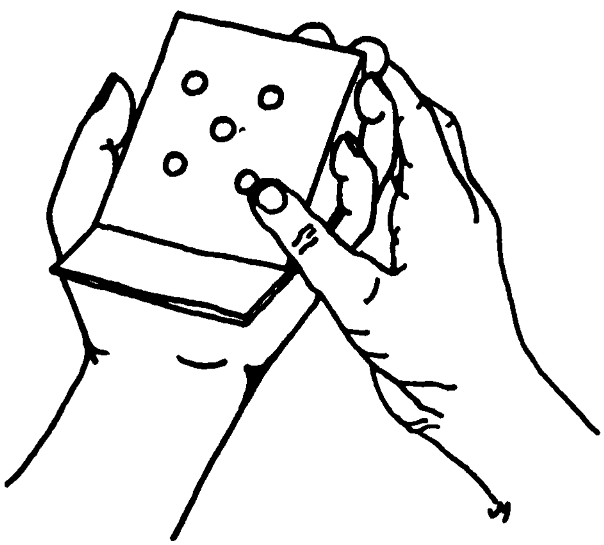
This study looks at inherent frequency as related to the cognitive task. The experiment tests the hypothesis that the EEG will reflect changes from condition to condition, i.e. as the task increases in rate of presentation and therefore in difficulty.

The most important contribution of this feasibility study is its contribution to experimental design and statistical analysis of EEG data. The rationale behind our experimental design should be of major importance to the Air Force because it focuses on the individual. This is very different from what has typically been done in Air Force-sponsored research. The Air Force has no responsibility to determine the average performance of the average college sophomore on any given task. What should be important to the Air Force is what pilot X will do on day y on his assigned task. It is this question that we attempt to answer. In short, we are interested in the performance of an individual subject rather than the average performance of some population of subjects. Not the least important reason for this philosophy is that the average score of a population often fits no individual case. For example, the average American family has 2.3 children, making it difficult to find the average American family. The point is that no pilot will exactly match the norms of his group. This is very true for EEG analyses of humans (Bremner & Moritz, 1972). It has been known for a long time that each subject has a unique EEG--as unique as one's fingerprints. This is even true of animal EEGs (Elazar & Adey, 1967; Bremner & Ford, 1968).

The Perelli Task (1980) is a cognitive task whose components are recognition, retrieval, reaction time, and discriminant responding. In this task, the several factors that need to be encoded by the subject are the symbol equivalents (see Figure 1), the spatial locations of the targets on the computer terminal screen (see Figure 1), and the spatial locations of the switches on the response panel (see Figure 1). The subject must retrieve from memory the number associated with the symbol presented, (the "?" in Figure 1), search for the correct number on the terminal screen, and then depress the switch on the response panel that has the same spatial location as the number on the screen. The correct button in Figure 1 is in the lower right hand corner.

After each response the target configuration changes as does the probe symbol. During the first few presentations the duration of the target array is directly under the subject's control. These are called "self-paced" trials. A mean reaction time is calculated from the self-paced trials and subsequently used as the duration for presentations during the next segment of the task. We call this the adaptive phase since the subject must adapt to the computer's pace. As the subject becomes faster, the targets are presented faster. Eventually, the subject cannot keep pace with the computer-driven target presentation rate. When the subject incorrectly responds to the target arrays, the computer slows down the presentation rate. When the subject fails to respond or responds incorrectly to two consecutive target arrays, the conditions for (blocking) cognitive overload are achieved. The programs falls back into the self-paced mode. When the subject has completed a second run through self-paced, adaptive, and blocking, the task terminates. We call this one run through the program; that is, each run contains at least two self-paced, two adaptive, and two cognitive overload segments. In addition,





The following associations
were memorized:

1 .... $
2 .... *
3 .... !
4 .... @
5 .... ?

Fig. 1. Picture of manipulation and visual display used by the Perelli Task.

the two cognitive overload segments must have presentation durations that are less than 200 msec apart.

Method (Study I)

Subjects

Twelve college students between the ages of 18-23 were subjects. This group consisted of nine females and three males. Each subject had three Beckman paste-on electrodes affixed in three areas: the right frontal, the left frontal and the vertex lead areas. None of the subjects had prior experience with this task.

Apparatus

Recordings of the EEG output were stored on a Sanborn eight channel analog tape recorder. During the recording of the EEG data, the TI 960 computer presented the cognitive task to the subject via an Intecolor display terminal (Intelligent Systems Corporation). The subject was tested in a sound proof Industrial Acoustics chamber which included the display terminal, the preamplifiers for the EEG monitoring, a chair with an adjustable head rest, and a response panel (Perelli, 1980). The preamplifiers (Data Inc., model 2124) were set at a gain of 3k, with high set at 30 and low set at .5. An oscilloscope (Tektronix) four channel, was used to visually monitor the sampling of EEG, and to detect the square waves on channel one, which indicated the subject's first and last responses. The Hewlett Packard (7858A) EEG amplifiers were set at .05 on channels two and three, and at .1 at channel one. The response panel was adapted from one used by the Air Force in a task developed by Captain Layne Perelli (1979). After the data was sampled, a computer program was written to A/D convert the data, and to analyze the data by a Fast Fourier Transform process.

Electrodes

Three Beckman paste-on electrodes (model 650418) were used. An ear ground was also used to minimize movement artifact.

Procedure

Each subject(S) was given a 3 x 5 card with the instructions to memorize the association between the five numbers and the five symbols. The S was then given a practice session in the sound proof chamber to practice the cognitive task, and to get comfortable wearing the electrodes. The S's head rest was adjusted before the task began to make the S as comfortable as possible, and to sustain him/her in a fixed position to minimize movement artifact. The S was read the standardized instructions for the task. The electrodes were affixed to the three designated areas of the head. A visual sampling of the EEG was noted from the oscilloscope at this time to check for movement artifact, and if this was detected, the subject was informed to relax and move as little as possible when responding.

Within a few days, a S returned to participate in the real experiment. The S was made comfortable in the sound proof chamber, and the electrodes were again attached. The computer program was initialized to begin the display of the task, and the EEG recording was started simultaneously. The computer program of the task included a presentation of a square wave on channel one of the tape deck. This indicated when the subject was responding to the self-paced trials at the beginning of the task, and when the subject was blocking at the end of the task. The experimentor recorded these square waves in terms of revolutions on the tape, so that the specific epochs of EEG could be A/D converted for later FFT analysis. The subjects mean reaction time and blocking scores were printed out by the computer giving a hardcopy of the behavioral scores.

The Task: Perelli Form A

The cognitive processing task is an adaptive one revised from the task developed by Captain Layne Perelli (USAFSAM) which involves associative memory load, memory scanning, visual scanning and a simple motor response (see interaction). This is a computer paced task which is adaptive to individual subject abilities. A 3 x 5 card contained the information for the subject to memorize:

"Please memorize the association between each number and symbol."

1 .... $

2 .... *

3 .... !

4 .... @

5 .... ?

Listed below are the standardized instructions:

"This is a human information processing experiment in which you will have to use the information you have memorized to perform a task. We will also be measuring your EEG during the experiment. In front of you is a terminal and a response panel. A display of numbers will flash before you on the screen in an array which is in the same formation as the response panel. It will look like this:" (see Figure 1).

The numbers will always be displayed in a random order, so the numbers in the various positions will always be different. Along with the display of numbers, a symbol, one of the five you have memorized, will appear to the right of the number display. Your task is to associate the symbol with the correct number, and to press the corresponding position of the number on the response panel. The task is designed so that you will have four self-paced trials in which you may respond at your own pace, and the

following trials will continually increase in speed, as you respond more quickly." (One display as in Figure 1 constituted one trial)

The Perelli task Form A was designed so that the computer first presented the S with four self-paced trials. The mean reaction time of these four trials was used as the beginning presentation rate of the adaptive phase of the task. During the adaptive phase of the task, the computer presented the stimulus arrays with shorter and shorter duration. The behavioral variable which was measured was the cognitive blocking score. The subject "blocked" when he/she did not respond correctly on two consecutive trials or stimulus arrays. At this point, the computer added 300 msec to the current presentation rate, to enable the S to "catch up" and resume responding. The run terminated when the subject blocked twice and these consecutive blocking scores were within 200 msec. Each subject was given two runs, and the final blocking score was taken as the behavioral variable of each subject.

Treatment of Results

Five of the twelve subjects EEG data were found as acceptable samples from the second run of the task; that is, they were artifact free. The five subjects EEG data were analyzed by an Analog to Digital conversion and Spectral Analysis computer program. This process converts the analog EEG record into a numerical series of discrete points which represent its frequency fluctuations over time. These discrete data points were inserted into a power spectral analysis equation called the Fast Fourier Transform or FFT (Benignus, 1969). The FFT section of the program analyzed one second of data taken during each of the three experimental conditions, the self-paced trials, early adaptive trials, and blocking trials, resulting in a power spectrum for each of the three epochs. The means and standard

deviations were computer for the 5 S's for 9-10 Hz. (alpha) and 4-5 Hz. (theta) frequencies, in the three experimental conditions. (See Figure 2)

Results

EEG Data

The mean percentage power scores for the alpha and theta frequencies in the three experimental conditions show apparent differences for the first (adaptive) and third (blocking) conditions. The populations in these two conditions at 9-10 Hz. are independent because these standard deviation scores do not overlap. (Figure 2) The blocking scores of each subject were sampled between 1-5 seconds prior to the subjects' final blocking score. This sampling varied for each subject since in order to find a clean sample of one second data at the end of the task. At that point, the task was presenting stimulus arrays more rapidly, and the S was generating more movement artifact than usual. No laterality differences were found between the left and right frontal samples. Therefore, only the graph for both sides added together is presented. (Figure 2)

Behavioral Data

The scores for the self paced and blocking trials for both the first and second run of the task show a definite learning effect. Notice that the Mean Reaction Time of the self-paced trials on the second run are much lower than that of the first run. These data are plotted in Figure 3.

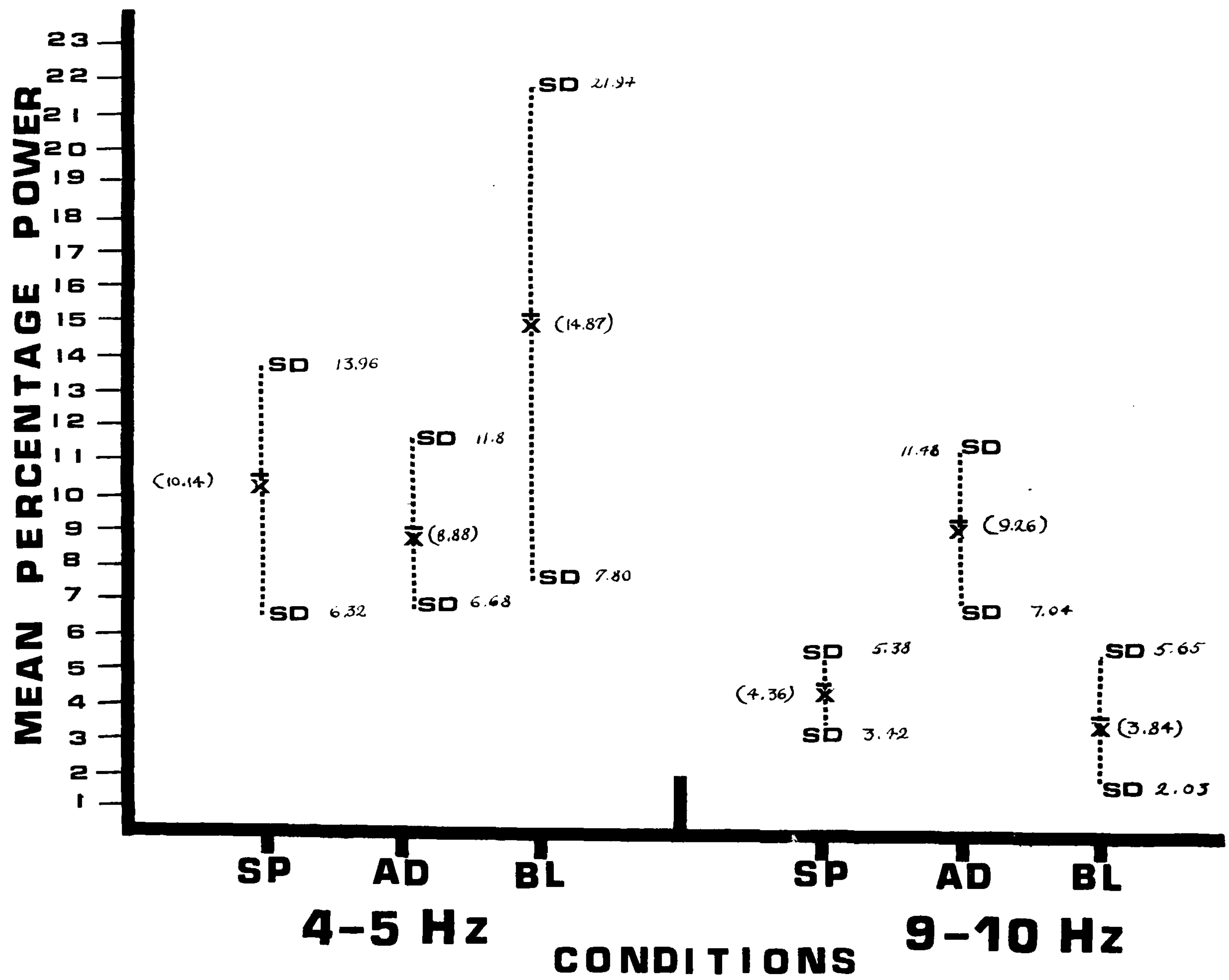

MEAN PERCENTAGE POWER
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
SD 13.96
(10.14)
SD 6.32
SD 11.8
(8.88)
SD 6.68
SD 21.94
(14.87)
SD 7.80
SD 5.38
(4.36)
SD 3.42
11.48 SD
(9.26)
SD 7.04
SD 5.65
(3.84)
SD 2.05
SP AD BL
4-5 Hz
SP AD BL
9-10 Hz
CONDITIONS

Fig. 2. Power spectrum distribution of 4-5 Hz. and 9-10 Hz. EEG during the Perelli Task.

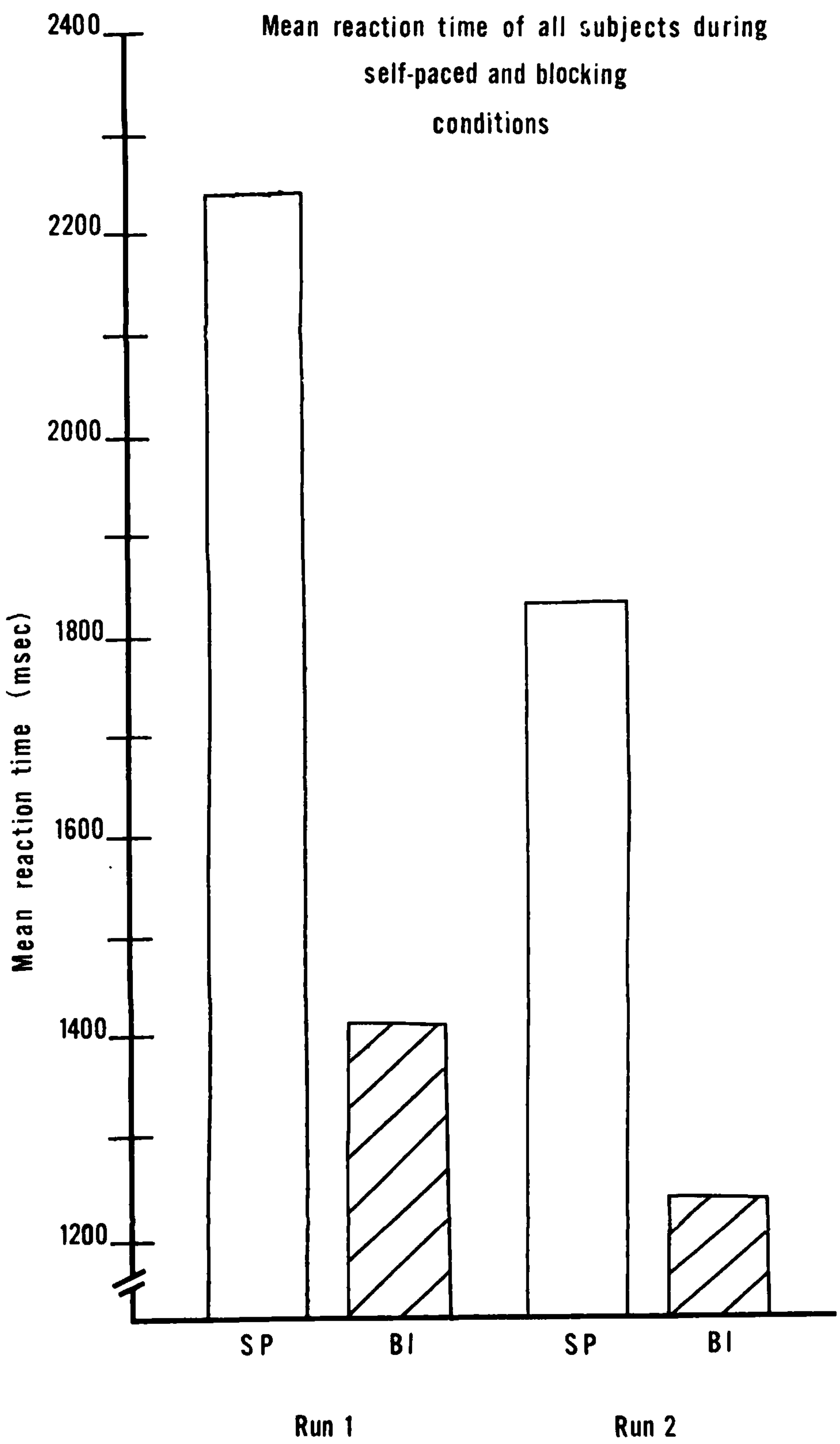

Mean reaction time of all subjects during
self-paced and blocking
conditions
2400
2200
2000
1800
1600
1400
1200
Mean reaction time (msec)
SP
Bl
SP
Bl
Run 1
Run 2

Fig. 3

Fig. 3. Histogram of reaction times of all subjects during the first and second run of the Perelli Task.

Discussion (Study I)

The 4-5 Hz. frequency shows a difference between the early adaptive conditions and the cognitive overload condition. There is also an apparent difference between self paced and blocking. Because the 4-5 Hz. and 9-10 Hz. values are precentages data, they are mirror images, that is, when the alpha percentage power is high, the theta percentage power is low. A possible interpretation of the results is that at the final blocking phase of the task the subjects are processing with a drastic increase of attention and effort, in order to keep up with the increasing speed of the task. Therefore, during cognitive blocking, the theta percentage power increases dramatically, and the alpha power decreases (i.e. alpha blocking) when compared to the self-paced or adaptive condition. A hypothesis explaining this phenomenon is that when someone is processing in the cognitive overload mode (high performance adaptive mode), they generate theta rhythm with a high percentage of power in the left and right frontal areas of the brain. Furthermore, this increase in theta could be indicative of intense cognitive processing. Studies have shown that theta increases during tasks which involve mathematical/ symbolic processing. This task does indeed involve the processing of symbols. Perhaps, these results are the same phenomenon.

One problem with the design of the EEG analysis was the sampling of EEG for the blocking scores. Because of sampling complications, the samples were taken from 1-5 seconds before the blocking score, and it was impossible to sample each subject in the same exact place. Since the sampling was not synchronized with any specific trials or coding device, the only known fact was that the subjects were in the blocking phase. It was not known precisely

what the subjects were doing at this point, whether they were responding to the present or previous trial, or whether they were responding to all. This fact must be taken into account when interpreting these data. Nevertheless, the author's contention is that the subjects were in the high performance adaptive mode.

No laterality differences were found between the left and right frontal samples. Perhaps this is because both electrodes were referenced to the same vertex lead, and a percentage power spectral analysis which normalized the data was used rather than an absolute spectra.

The blocking and self-paced response scores for the first and second runs showed a learning effect. Perelli (1980) also showed a learning effect in his data, but his subjects showed much lower blocking scores; with a mean of approximately 700 msec. for all subjects. It must be mentioned that there were differences in experimental design of these two studies. Perelli's subjects have five to six more hours of practice time with the task. Furthermore, the design of this task differs from Perelli's because this task does not account for whether the subject is responding to the preceding or immediate trial. In comparing Perelli's subjects and the subjects of this experiment, it is possible to detect a motivational effect, also. Perelli's subjects were pilots in training who were highly motivated to perform well in the interest of their careers. The subjects of this study were students who gained no monetary benefit or class credit for their participation. Although Perelli's subjects' blocking scores were different from the blocking socres of this study, in view of the behavioral data, both studies had mean values which were significantly above 500 msec. With 500 msec. representing a baseline for simple reaction time (Woodworth and Schloberg, 1956), a higher mean value would

indicate something more than simple motor response. These higher mean values might indicate some higher level of cognitive processing in both studies. Both the EEG and behavioral data suggest the presence of cognitive processing. The EEG data indicates that increased theta in frontal electrodes is a possible predictor of cognitive processing in the high performance adaptive mode.

Study II

Upon completion of Study I it was apparent that while the EEG from the frontal electrodes demonstrated the predicted effect the data contained too much artifact. Moreover, this artifact was most prevalent during the high performance cognitive overload condition. Several tests were conducted in our laboratory which convinced us that improved technique in electrode placement and changing the reference electrode from the vertex to the ear would considerably improve the quality of EEG data recording. We also suspected that other more posterior electrode sites would be more artifact free since eye blinks and brow wrinkling would affect them less. We, therefore, determined to use six electrodes not only because of the artifact problem but to increase the data sample (provide more measures of the dependent variable).

In addition, we determined to test enough subjects so that statistical comparisons could be made and to use absolute power spectra rather than percentage power spectra. Therefore, Study II was conducted with these modifications of Study I before us.

Method (Study II)

Subjects

Twenty subjects, ten males and ten females, were selected from a subject pool consisting of undergraduate psychology students at Trinity University, San Antonio, Texas. The subjects were given extra-credit points or paid $20.00 in exchange for their participation in the experiment. None of the subjects had prior experience with the task.

Apparatus

A TI 960 computer presented the cognitive task to the subject via an Intecolor display terminal (Intelligent Systems Corporation). Subjects were tested in a sound proof Industrial Acoustics chamber which contained a well-padded chair, the display terminal, a response panel (Perelli, 1980), the preamplifiers for the EEG monitoring, and paraphenalia necessary for EEG instrumentation. The preamplifiers (Data, Inc. model 2124) were set at a gain of 5k, with high frequency filters at 50 and low frequency filters at 1. The EEG signals were sent through a Beckman Type T 450 Encephalograph demodulator filter amplifier outside the chamber. A Tektronix four channel oscilloscope (model 5110) was used to visually monitor the sampling of EEG, and to detect the square waves which indicated the subject's responses. Recordings of EEG output were stored on a Crown eight channel analog tape recorder (model 700). Simulated wave forms of known characteristics were recorded for calibration before and after the subject's EEG. Statistical manipulation of the results were performed on a IBM 3031 computer.

Electrodes

Six electrode sites were monitored from each subject. Two Beckman paste-on electrodes were affixed to the left frontal and right frontal areas. Four Grass pin electrodes were placed as follows, bilaterally over the occipital area and bilaterally in the high central area.

Procedure

Each subject was given a practice session in the sound proof chamber. In this session the conditions of the experiment were explained and standardized instructions for the task were read to the subject. (Each subject was asked to memorize the association between five numbers and symbols before coming

into the experimental setting.) The subject performed the cognitive task several times and was asked to return in a few days. This time the subject was instrumented for EEG and a visual sampling of the EEG was inspected to check for artifacts. A neck pillow was adjusted to make the subject comfortable and keep his/her head still. The subject was reminded to move as little as possible when responding. The computer program was initialized to begin display of the Perelli task and the recording of EEG was started simultaneously. When the task was over the subject was allowed to rest for a moment and the procedure was repeated.

The Task (Form B)

The cognitive processing task is a revision of the task developed by Captain Layne Perelli (USAFSAM). It is an adaptive task which involves associative memory load, memory scanning, visual scanning, and a simple motor response. The task is computer paced and adaptive to individual subject abilities (see Introduction and Study I).

In Form B only 200 msec. is added to the stimulus array presentation rate rather than the 300 msec used in Form A.

Treatment of Results

EEG samples across three experimental conditions were studied. These conditions were defined as self-paced, adaptive, and blocking. A total of ten one second epochs of EEG data from each of the three conditions (i.e. ten seconds self-paced, ten seconds adaptive, and ten seconds blocking) were analog to digital converted. These epochs were obtained from three task runs. (For example, four one second epochs were sampled from the self-paced phase of the subject's first run, and three one second epochs

were taken from each of the second and third runs (for details see Appendix A). This analysis procedure was repeated for each of the twenty subjects. The process converts the analog EEG record into a numerical series of discrete points which represent its frequency fluctuations over time. These discrete data points were then inserted into a power spectrum analysis program, Fast Fourier Transform (FFT) (Benignus, 1969). The output of this FFT algorithm provides a histogram of the absolute power present at each condition. These outputs, called spectra, were further analyzed by Factor Analysis and Partial Correlation.

Results (Study II)

The absolute power spectra of the EEG from 4 to 11 Hz. were subdivided into two hertz band widths. Each of these two hertz band widths was made a variable in a factor analysis. Therefore, four variables (two in the theta and two in the alpha frequency range) were studied. Variable one was 4-5 Hz., variable two 6-7 Hz., variable three 8-9 Hz., while variable four was 10-11 Hz. Principal factoring with iterations and varimax rotation was performed on each of the six electrode sites under each of the three conditions. The overall results show a tendency for inherent frequencies to change as the cognitive task gets more difficult (i.e. from self-paced to adaptive to cognitive blocking).

Table 1 summarizes the factor matrices obtained by the analysis of the frontal leads. Both frontals appear consistent across the three experimental conditions. Using a pre-selected cutoff factor score of .70 we find the lower frequencies on both the right and left side correlate highly with the first factor in all conditions. Likewise, the second

Table 1

Factor Matrix of the Frontal Leads for Four

Variables, Across Three Conditions

CONDITION	VARIABLE	ELECTRODE			
		Left Frontal		Right Frontal	
		Factor I	Factor II	Factor I	Factor II
Self-paced	Var 1 (4 - 5 Hz.)	.76		.79	
	Var 2 (6 - 7 Hz.)	.89		.96	
	Var 3 (8 - 9 Hz.)	.77		.76	
	Var 4 (10 - 11 Hz.)	.52		.58	
Adaptive	Var 1	.89		.71	
	Var 2	.99		.96	
	Var 3	.68		.47	
	Var 4	.39		.71	
Blocking	Var 1	.85	.35	.82	.16
	Var 2	.90	.05	.89	.14
	Var 3	.45	.78	.37	.72
	Var 4	.03	.82	.01	.70

Table 2

Factor Matrix of the High Central Leads

for Four Variables, Across Conditions

CONDITION	VARIABLE	ELECTRODE	
		Left Central Factor I	Right Central Factor II
Self-paced	Var 1 (4 - 5 Hz.)	.84	.80
	Var 2 (6 - 7 Hz.)	.86	.94
	Var 3 (8 - 9 Hz.)	.95	.73
	Var 4 (10 - 11 Hz.)	.74	.53
Adaptive	Var 1	.88	.63
	Var 2	.98	.98
	Var 3	.73	.90
	Var 4	.71	.70
Blocking	Var 1	.90	.99
	Var 2	.84	.74
	Var 3	.76	.64
	Var 4	.67	.41

Table 3

Factor Matrix of the Occipital Leads for

Variables, Across Three Conditions

CONDITION	VARIABLE	ELECTRODE			
		Left Occipital		Right Occipital	
		Factor I	Factor II	Factor I	Factor II
	Var 1 (4 - 5 Hz.)	.00		.35	
Self-paced	Var 2 (6 - 7 Hz.)	.34		.68	
	Var 3 (8 - 9 Hz.)	.99		.64	
	Var 4 (10 - 11 Hz.)	.76		.99	
	Var 1	.66		.53	
Adaptive	Var 2	.98		.68	
	Var 3	.82		.94	
	Var 4	.37		.89	
	Var 1	-.02		.72	
Blocking	Var 2	.92		.88	
	Var 3	.93		.47	
	Var 4	.77		.86	

variable (6-7 Hz.) correlates most hihgly with the first factor at a level of .90 or more across both sides and all three conditions. In short the theta frequencies correlated with the first factor and that correlation improves as you go from self-paced to blocking.

Using the cutoff factor score of .70, it is difficult to discern a pattern across conditions when looking at the high central electrode sites. (See Table 2.) However, there is an obvious trend if the variable most highly correlated with the factor is examined. In short, as the difficulty of the task increases, there is a tendency for the dominant frequency to become slower. On the left side, variable three (8-9 Hz.) is most highly correlated with the factor during the self-paced conditions, during the adaptive phase variable two in most highly correlated, and in the blocking condition variable one (4-5 Hz.) is most represented. On the right side, variable two (6-7 Hz.) is most highly correlated with the factor during the self-paced and adaptive conditions. During blocking it is variable one which is dominant.

One can also differentiate among conditions when studying the factor matrices of the occipital leads which are illustrated in Table 3. However, unlike the centrals, it is not the highest correlated variable which is notable, but those variables with a correlation of about .70 or higher. In condition one, variables three and four (alpha) of the left side correlate with Factor I and variables one and two correlate with Factor II. In condition two, variables one, two and three correlate, indicating a shift towards the slower frequencies. In blocking, high alpha--variable four is introduced and low theta--variable one is eliminated. On the right side there is no apparent shift between conditions one and two, with variables

two, three, and four correlated. In condition three, the variables are split, with most of the correlation falling in the lower frequencies, variables one and two.

Partial correlations were also performed on the left occipital data. For condition one, the results compliment the factor analytic conclusions. That is, the partial correlation of variables three and four is quite strong ($\underline{r}_{34.12} = .77$, $\underline{p} < .01$) as is the partial correlation of variables one and two ($\underline{r}_{12.34} = .72$, $\underline{p} < .01$). Since factor analysis of condition two resulted in only one factor, it would be redundant to report partial correlations for the four variables. Likewise, for condition three the factor distribution is such that a partial correlation is meaningless. Clearly, the partial correlational patterns support the factor analytic conclusions for this condition. For example, looking at a partial correlation of variables one and four in condition three, we find the results to be quite trivial ($\underline{r}_{14.23} = -.12$, $\underline{p} < .05$) as would be logically anticipated from the factor analysis.

Discussion (Study II)

The factor analysis of the EEG from the frontal electrodes does support the first study. In particular the theta range frequencies (variable 1+2; 4-7 Hz.) correlate most highly with the task and this correlation improves as the 20 subjects go from self-paced to cognitive overload. Moreover, the alpha range frequencies (variable 3,4; 8-11 Hz.) becomes less correlated as the 20 subjects proceed from self-paced to cognitive overload as would be expected from the first study. While not as apparent the factor analysis of the central electrodes statistics is also consistent with the profile presented above that is theta range frequencies are highly correlated with the

task and the correlation contrasts that of the alpha range frequencies. This is most apparent during the cognitive overload condition when 4/5 Hz. is the highest correlated variable while 10/11 Hz. is the least correlated with the factor. The occipital electrodes were of particular interest since they showed an apparent difference between right and left electrode. The right occipital follows the general profile presented above in that the correlation of theta range frequencies increase as the 20 subjects go from self-paced to cognitive overload while the correlation of alpha range frequencies decreases. This is best shown by comparing self-paced to cognitive overload. The left occipital electrode, however, does not show this same trend. This might reflect a laterality difference.

Nevertheless, the data from the frontal and high central leads do support the experimental hypothesis. That is, a difference in EEG for the respective conditions is demonstrated. Since all subjects were required to perform the task with their right hand, it is interesting to note that the high centrals show no lateral differences, although these leads are closest to the motor cortex. Perhaps verbal and geometric input is being processed equally by both hemispheres at these electrode sites. The high centrals do discriminate the task, however, which leads one to suspect change due to some cognitive function. Recent research in brain electrophysiology indicates that there may be relationships between different inherent brain wave frequencies and cognitive processing (Hyman, 1978). An alternative explanation may be that the EEG sampling techniques of this study were not refined enough to recognize differences between the two hemispheres.

The occipital leads did, however, descriptively show both task and

apparent hemispheric differences. The occipital cortex should be the least affected by motor processing, eye blink or muscle artifacts. These results indicate, therefore, that the subject is doing something different with the two visual cortices.

It has been suggested that increased theta may be a possible predictor of cognitive processing in the high performance adaptive mode (Birkeland, 1979). The high central and occipital leads show an increase in theta as the cognitive task grows increasingly difficult.

The results of this study indicate that inherent brain waves may reflect different modes of cognitive processing. It is possible that further analysis will result in the identification of predictor variables indicative of cognitive states. Predictor variables would be beneficial in determining to what limits humans can perform and process cognitive information.

Study III

Upon completion of Study II several factors about the data and its correlation with the task were apparent. As an example there is the difference in correlation between right-left occipital electrodes of 4/5 Hz. during the cognitive overload phase of the Perelli Task. Since the right occipital electrodes showed the typical trend of right-left frontals and right-left centrals, it was important to determine if the apparent difference in the left occipital was real or a reflection of the group statistics process. An alternative hypothesis or explanation of these data could be just the effect of individual EEG differences of the 20 male and female subjects used. In order to ascertain this, we systematically inspected the individual subject data both visually and with statistical tools. We felt that individual subject differences were of extreme importance in this research and that there was indeed a possibility that the occipital electrodes were being widely influenced by individual subject differences. We, therefore, began library research on the use of single subject statistical methods and found that Kelly and his associates (1969) had developed the techniques that we needed for EEG. While Kelly (1973) used these statistical techniques on single subjects, Skinnerian cumulative recordings his research philosophy lead us to the statistical analysis technique presented in Study III.

The experimental design used in Study III attempted to further reduce variability in the data set. This was done by concentrating on the occipital electrodes previously shown to be most resistant to movement artifact and to monitor the outer canthus to detect eye blinks. We intended

to further reduce variability by having only one gender in this study and to both increase the number of experimental sessions and the number of runs through the Perelli Task within a given session. It was further decided to introduce control conditions that would relax the subjects and at the same time provide a contrasting data sample under cognitive conditions very different from the Perelli Task.

The control conditions were deep relaxation (Barnes & McKenzie, 1976), biofeedback (Bremner, Moritz, Benignus, 1972), and hand levitation (Hyman, 1978). The rationale for picking these conditions are twofold: (a) to relieve subject tension and (b) to produce EEG predominantly in the alpha range (Hyman, 1978; Bremner, 1972; McKenzie, 1974) thus contrasting the Perelli tasks which produces EEG predominantly in the theta range (see Study I and II above). Finally, we proposed to capitalize on single-subject totally within time series analysis statistical procedures.

Method (Study III)

Subjects

Eight male subjects, 18-26 years old, were selected from a subject pool consisting of students at Trinity University, San Antonio, Texas. The subjects were paid $25.00 ($5.00 an hour) in exchange for their participation in the experiment. None of the subjects had prior experience with the task.

Apparatus

A TI 960 mini computer presented the cognitive task to the subject via an Intecolor display CRT terminal (Intelligent Systems Corporation). Subjects were tested in a sound proof Industrial Acoustics chamber which contains a well-padded chair, the display terminal, the preamplifiers for the EEG monitoring, and paraphenalia necessary for EEG instrumentation. Also included was a hand-held five-place response panel (Wilkinson, 1975) which provides subject input to the TI 960 computer (See Figure 1). The preamplifiers (Data, Inc., model 2124) were set at a gain of 5k, with high frequency filters at 50 and low frequency filters at 1. The EEG signals were sent through a Beckman Type T 450 Encephalograph demodulator filter amplifier outside the chamber. A Tektronix four-channel oscilloscope (Model 5110) was used to visually monitor the sampling of EEG, and to detect the square waves which indicate the subject's responses. Recordings of EEG output were stored on a Crown eight-channel analog F. M. tape recorder (model 700). Simulated wave forms of known characteristics were recorded for calibration before and after the subject's EEG. Statistical manipulation of the results were performed on an IBM 3031 computer.

Electrodes

Four EEG electrode sites were monitored from each subject and a Beckman paste-on electrode was affixed to the outer canthus to detect eye blink artifacts. Two of the EEG electrodes were Grass pin electrodes placed bilaterally over the occipital area while the other two were placed bilaterally on the high centrals. A paste-on electrode was placed on each earlobe and the EEG recorded between the cortical electrodes and the ipse-lateral ear. A paste-on electrode was placed on the ionion as a ground to minimize movement or electrical artifacts. In addition, two EKG electrodes were placed on both sides (lower left and upper right) of the sternum.

Procedure

Four subjects comprised series I with the remaining four assigned to series II. Each subject in series I was given two practice sessions (three for series II) in the sound proof chamber. In these sessions the conditions of the experiment were explained and standardized instructions for the task read to the subject. (Each subject was asked to memorize the association between five numbers and symbols before coming into the experimental setting (See Figure 1). The subject listened to the guided imagery relaxation induction tape (McKenzie, 1980) for eight minutes and then performed the cognitive task four times and was then asked to return the next day. This time the subject was instrumented for EEG after signing an informed consent form (attached), and a visual sampling of the EEG was inspected to check for artifacts. A neck pillow was adjusted to make the subject comfortable and keep his head still. The subject was reminded to move as little as possible when responding. This experimental procedure was the same as in the practice sessions except that the EEG was recorded throughout. Each subject

was then required to return five more times on five consecutive days (4 days for series II) to repeat the EEG recording procedure.

The Control Task Procedures

The eight-minute relaxation induction procedure was condensed from a longer twenty-minute version developed by Dr. R. McKenzie (1980). The prerecorded cassette contains instructions designed to guide the listener's internal imagery in such a manner as to produce a state of relaxation. This relaxed state was maintained through periods during which the listener's eyes are closed and then later when they are open. The relaxation procedure occurs once at the beginning of each daily testing session and is followed by a paralogical hand levitation task for series I and a biofeedback procedure for series II. The biofeedback procedure utilized a filter (manufactured in house) (Helmer, 1975) tuned for 10 Hz. which could be switched on line into one channel of the Beckman 450 demodulator filter amplifier. Audio feedback of the filtered output of channel 6 (right occipital) was presented to the subject via a Realistic MC 500 enclosed speaker. Subjects were instructed to maintain as much continuous feedback sound as possible first for 30 seconds with their eyes closed and then for another 30 seconds with eyes open. The hand levitation procedure is a paralogical or meditation task in which a subject is required to raise his hand from lap to chin without conscious volition (Hyman, 1978). A typical session was as follows: (a) instructions, (b) relaxation, (c) biofeedback or hand levitation depending on group assignment, and (d) six runs through the Perelli Task.

Perelli Task Form C

Form C is similar to Forms A and B except during the adaptive phase. Remember, during the adaptive phase the trials are presented as successive

decrements of milleseconds. Thus, the rate of presentation continually increases. In Form C any incorrect or missed response increments the presentation rate by fifty milleseconds rather than 200 msec. as in Forms A and B. The final phase of the task, the "block," is still defined as the lack of response to two consecutive stimulus presentations. When a subject "blocks," the computer adds two hundred milleseconds to the current presenation rate to enable the subject to "catch-up" and resume responding. The experiment terminates when consecutive blocking scores are within two hundred milleseconds (i.e., one run through the task). Each subject had six runs through the task per day under Form C of the Perelli task. The reaction time for each trial is printed out by the computer, giving a hard-copy profile of each subject's performance.

Treatment of Results

Brain wave samples were taken during the deep relaxation procedure, biofeedback or hand levitation procedures and the three cognition task subdivisions (that is, self-paced, adaptive and cognitive overload). The eyes open sample taken during the relaxation induction procedure and biofeedback or hand levitation procedure served as a baseline control. A total of 20 one-second epochs of EEG data, free from eye blinks and muscle artifacts, sampled from the baseline conditions and each of the cognitive subdivisions (that is, 20 seconds relaxation, 20 seconds hand levitation or biofeedback, 20 seconds self-paced, 20 seconds adaptive, and 20 seconds cognitive overload) were analog-to-digital (A/D) converted (see Appendix A). This analysis procedure was repeated for each of the eight subjects for the first and last day of testing. The A/D process converted the analog EEG record into a numerical series of discrete points which represented its frequency fluctuations over time. These discrete data points were then inserted into a power spectra, analysis program, Fast Fourier Transformation (FFT) (Benignus, 1969). The output of this FFT algorithm provided a histogram of the absolute power present at each condition. These outputs, called spectra, were further analyzed by a single-subject statistical design using time-series analysis techniques (Kelly et.al., 1969). The decision to use a single-subject design was based on results obtained from the factor analysis with 20 subjects which demonstrated large variability between subjects (Verosky, 1980).

The analysis compared the two baseline conditions and all three subdivisions of the cognitive task within each day. That is, there were five spectra for each subject for each day, for each electrode. Since there were

four electrodes (right and left occipitals and centrals) the total number of spectra per day was 30. We decided to use just the first and last day and only the occipital electrodes in an attempt to reduce the analysis effort. Nevertheless, there was a total of 40 spectra for each subject.

Additional statistical procedures were applied to these 20 spectra for each subject. The last day's spectra for each subject were tested by a discriminant analysis to determine what we call the indicator frequencies. This single subject design procedures (Kelly, 1969) works as follows: The data for the last day was submitted to a discriminant analysis (Yost, 1965) with seconds rather than subjects being the between variable. Brain wave frequencies were the variable (4 - 11 Hz.). Table 4 contains a typical output. The Table 4 data were used to pick four indicator frequencies. Two in the alpha range and two in the theta range. The frequencies picked for this subject were 4, 6, 9, and 10 Hz. These frequencies were picked because they were highly correlated with one of the significant roots and have a rare probability of occurring by chance.

The next step in the analysis process was to test for difference between conditions botn cognitive and non-cognitive and also between days but within a single subject (See Table 4). This was done by submitting the four indicator frequency scores to a manova. If a significant difference between conditions was found (the omnibus test) orthogonal, comparisons were applied.

Table 4

CONDITION

1. 20 seconds relaxation
2. 20 seconds biofeedback
3. 20 seconds self-paced
4. 20 seconds adaptive
5. 20 seconds cognitive overload

$p < .0003$ on df = 32 and 326, F ratio = 2.275

CORRELATION OF ROOTS WITH VARIABLE		PROBABILITY OF VARIABLE (F TEST)		
Hz.	Sig Root I	Hz.	F/Ratio	P
4	-.48	4	2.95	.02*
5	.15	5	.78	.54
6	.44	6	2.34	.05*
7	.19	7	.89	.52
8	.24	8	1.13	.34
9	.86	9	12.22	.0000*
10	.55	10	3.80	.006*
11	.14	11	.45	.76

χ^2 11Df, $P < .0001$

Results (Study III)

The results of the manova on each of the eight subjects is presented in Table 5. These effects were obtained by applying a manova to the EEG of each subject for right and left occipital electrodes. The power scores at frequencies 4 Hz., 5 Hz., 10 Hz., 11 Hz. were used as data in the manova. These four frequencies 4, 5, 10, 11 Hz. were arrived at by applying the discriminant analysis to each subject's right and left occipital electrode as described above. When we had the 16 discriminant analyses in hand (eight subjects with two electrodes each) we decided to pick a set of frequencies that could be used for all eight subjects. This best compromise set of frequencies was found to be 4 Hz., 5 Hz., 10 Hz., 11 Hz. The manova applied to each of these frequencies always had a significant root when the omnibus manova test was applied (except subject #1 right occipital). The four orthogonal contrasts applied were the following: (1) Relaxation and hand levitation (the controls) versus self-paced, adaptive, cognitive overload (the three cognitive conditions); (2) Relaxation (Control I) versus hand levitation or biofeedback (Control II) and all three cognitive effects; (3) Self-paced versus cognitive overload; (4) adaptive versus cognitive overload. Note that the control conditions are significantly different from the three cognitive conditions in all cases except the right occipital electrode for subject #1. This means this effect was significant in 15 out of the 16 electrodes tested. The relaxation (Control I) versus all others was also significant in 11 of the 16 electrodes tested. Differentiating the cognitive states was not as reliable as the first orthogonal contrast but adaptive was found significantly different from cognitive overload in 11 of

Table 5

		Significant Effects (4, 5, 10, 11 Hz.) Control Versus Cognitive 4 and 92 df			Relaxation Versus Other Four Conditions on 4 and 92 df			Adaptive Versus Blocking on 4 and 92 df		
		F	P<	R	F	P<	R	F	P<	R
Subject #1	L occ.	3.0	.02	.34	3.0	.02	.34	1.3	.26	.23
	X R occ.	-	-	-	-	-	-	-	-	-
2	L occ.	6.7	.001	.47	7.6	.001	.50	.52	.75	.15
	R occ	6.5	.001	.46	7.7	.001	.50	.95	.43	.20
3	L occ.	12.5	.001	.59	10.0	.001	.55	6.0	.001	.45
	R occ.	6.5	.001	.46	9.1	.001	.53	4.3	.003	.39
4	L occ.	4.6	.002	.40	2.6	.04	.32	3.3	.01	.35
	R occ.	6.5	.001	.47	3.7	.007	.37	4.3	.003	.39
5	L occ.	7.0	.001	.48	2.2	.07	.29	5.7	.001	.48
	R occ.	6.3	.001	.46	1.5	.18	.25	5.4	.001	.43
6	L occ.	10.9	.001	.56	4.7	.002	.41	4.0	.005	.38
	R occ.	10.0	.001	.55	5.3	.001	.43	7.0	.001	.48
7	L occ.	5.7	.001	.44	2.0	.09	.28	4.2	.003	.39
	R occ.	11.2	.001	.57	2.7	.03	.32	8.1	.001	.51
8	L occ.	11.2	.001	.57	2.5	.04	.31	6.3	.001	.46
	R occ.	8.8	.001	.52	1.9	.10	.28	4.1	.004	.39

[X]Subject #1 right occ. had a non-significant omnibus test and was not analyzed.

of the 16 cases while self paced was significantly different from cognitive overload in 8 of the 16 electrodes tested.

The obvious interpretation of Study III is that a technique has been found to differentiate the EEG during the cognitive and non-cognitive tasks. In particular, the control conditions of deep relaxation, biofeedback and hand levitation are statistically different from the cognitive components of the Perelli task. Moreover, the cognitive component of the Perelli task are statistically different from each other (self paced from blocking and adaptive from blocking). Finally, deep relaxation is statistically different from all other conditions.

Our interpretation of these results is that the occipital leads are processing differently depending on the task which the subject is doing. This statistical different in the EEG sampled during the six behavioral conditions of this study supports the findings of Study I and III. That is, the indications of the five subjects reported in Study I that theta range frequencies predominates 4/5 Hz. are highly correlated with the Perelli task and this correlation improves the more difficult the task becomes; this has been shown to be statistically reliable in every subject tested in this study (self paced versus blocking and adaptive versus blocking). Moreover, the fact that alpha frequencies (10/11 Hz.) are not well correlated with the Perelli task and that what correlation there is decreases as the task gets more difficult is well supported by Study III. The statistical difference between control conditions and cognitive conditions is usually based on the fact that 10/11 Hz. predominates during the control conditions while 4/5 Hz/ predominates during the cognitive conditions. Nevertheless, the apparent laterality effect seen in Study II was not found to be statistically reliable in Study III.

Summary

The rationale of the present feasibility study was to test the efficacy of using EEG measures to assess the level of cognitive processing in aircraft pilots. We believe that on the basis of this study that it is indeed possible to use EEG measures to differentiate cognitive states. Several studies involving different subjects under differing conditions demonstrated the relationship between EEG and cognitive states. Study I, with five subjects, had two frontal EEG electrodes referred to a vertex indifferent. The resulting EEG showed that there was a difference between cognitive conditions. Close inspection of the EEG analyses and our past experience with other EEG leads us to believe that frontal EEG electrodes alone were inadequate to capture the most significant data.

Study II, with 20 subjects, used six electrodes (two frontals, two centrals and two occipitals) referred to the ears as the indifferent electrodes. The results showed that the best statistical indicator of differences in cognitive states was the occipital electrodes. Moreover, the individual subject variability suggested that the experimental design might profit by having additional control data on each subject. In Study II ten of the twenty subjects were also given a deep relaxation exercise. The EEG recorded during the deep relaxation contrasted sharply with that recorded during the cognitive task. It was also apparent that the EEG patterns were being distorted by individual subject differences. In Study III eight subjects were tested in a statistical design using each subject as its own control and having both cognitive and control tasks presented in close temporal proximity. Statistical tests showed that the EEG could be used to clearly differentiate cognitive and noncognitive tasks.

The most important contribution of this study is the development of a technique to statistically analyze the effects of various treatments on EEGs while using the subject as his own control. We refer to this time series analysis as INNOVATE (Individual Nominal Variant Analysis Technique).

References

Barnes, R. H. & McKenzie, R. E. Biofeedback in General Psychiatric Practice. World Journal of Psychosynthesis, May-June, 1976.

Benignus, V. Computation of Coherence and Regression Spectra Using the FFT. Common, 1969.

Birkeland, D. J. Honor's Thesis, Trinity University, San Antonio, Texas, 1979.

Bremner, F. J., & Moritz, F. J. Internal Focus as a Subset of Attention. Neuropsychologia, 1972, 10, 467-469.

Bremner, F. J., Moritz, F., & Benignus, V. EEG Correlates of Attention in Humans. Neuropsychologia, 1972, 10, 307-312.

Ehrlichman, H., & Winer, M. S. Consistency of task related EEG asymmetries. Psychophysiology, 1979, 16, 247.

Elazar, Z., & Adey, W. R. Spectral analysis of low frequency components in the electrical activity of the hippocampus during learning. Electroencephalograph Clinical Neurophysiology, 1967, 23, 225-240.

Gevins, A. S., Zeitlin, G. M., Doyle, J. C., Yingling, C. D., Schaffer, R. E., Callaway, E., & Yeager, C. L. EEG correlates of higher cortical functions. Science, 1979, 203, 665-667.

Hyman, P. Master's Thesis, Trinity University, San Antonio, Texas, 1978.

John, E. R. Neurometrics. Science, 1977, 196, no. 4297, 1393-1409.

Kelly, F. J., Beggs, D. L., McNeil, K. A., Eichelberger, T., & Lyon, J. Multiple Regression Approach. Carbondale: Southern Illinois University Press, 1969.

Kelly, Francis J., McNeil, Keith, & Newman, Isadore. Suggested inferential statistical models for research in behavior modification. The Journal of Experimental Education, 1973, 41, no. 4, 54-63.

McKenzie, R. E., Ehrisman, W. J., Montgomery, P. S., & Barnes, R. H. The treatment of headaches by means of electroencephalographic biofeedback. Headache, 1974, 13(4).

McKenzie, R. E., & Hartman, B. O. Chapter 6, Some insights relative to the man-machine system: an overview of ten years of research. Survey Methods to Assess Workload. AGARDograph No. 246, 1979.

McKenzie, R. E. Personal Communication, 1980.

Morgan, A. H., McDonald, H., & Hilgart, E. R. EEG alpha: lateral asymmetry related to task and hypnotizability. Psychophysiology, 1974, 11, 275-282.

Perelli, L. Doctoral Thesis, Catholic University, St. Louis, Missouri, 1980.

Tiechner, W. H., & Olson, D. E. A preliminary theory of the effects of task and environmental factors on human performance. Human Factors, 1971, 13(4), 295-344.

Verosky, P. EEG Inherent Frequency Correlates of Cognitive Processing. Unpublished honors thesis, Trinity University, San Antonio, Texas, 1980.

Wiener, E. L., & Keeler, L. F. Adaptive strategies in vigilance research. Ergonomics, 1975, 18(4), 403-414.

Woodworth, H. & Scholsberg, R. S. Experimental Psychology (rev. ed.). Henry Holt & Co., Inc., 1956.

Wilkinson, R. T., & Houghton D. Portable four-choice reaction time test with magnetic tape memory. Behavior Research Methods and Instrumentation, 1975, 7, 441-446.

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The rationale of the feasibility sutdy was to test the efficiency of EEG measures in assessing the level of cognitive processing in aircraft pilots. Several studies involving different subjects under differing conditions demonstrated the relationship between EEG and cognitive states. Frontal electrodes alone were inadequate to capture the most significant data. The best statistical indicator of differences in cognitive states was the occipital electrodes. Statistical tests showed that the EEG could be used to clearly differentiate cognitive and non-cognitive tasks. The study's most important contribution

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was the development of a technique for statistically analysing various treatment effects on EEG while subjects are used as their own control. This time series analysis is referred to as INNOVATE (Individual Normal Variant Analysis Technique).